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EVALUATION OF CRITICAL SUCCESS FACTORS FOR BUSINESS INTELLIGENCE SYSTEMS USING FUZZY AHP

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ABSTRACT

Business intelligence systems (BIS) play an important role in organizations through enabling managers and decision-makers to make accurate, timely and relevant decisions to increase the productivity and profitability of their organizations. To be able to consolidate resources, the prioritization of critical success factors (CSFs) need to be determined. This study articulated sixteen CSFs of BIS based on the previous researches and classified them into four categories. To find out their relative priorities, Fuzzy Analytic Hierarchy Process (FAHP) has been used. Twelve BI experts were asked to pairwise rank the success factors of business intelligence system to conclude that organizational and technological should be the top priority for BIS projects. In addition, that top management support, proper BI vendor selection and adequate resources availability are more important than the other thirteen factors.

Keywords: *Business Intelligence System, Critical Success Factors, Fuzzy Analytic Hierarchy Process.*

1. INTRODUCTION

Now a day's academics and practitioners give much attention to business intelligence systems, because of their effect on corporate performance management [1]. The term Business Intelligence was defined in different ways and there is no universally accepted definition of BI. Many researchers defined BI as a broad category of applications, technologies, and processes for gathering, storing, accessing, and analyzing data to help its users make better decisions [2, 3]. Business Intelligence (BI) includes several software for Extraction, Transformation and Loading (ETL), data warehousing, database query and reporting, multidimensional/on-line analytical processing (OLAP) data analysis, data mining and visualization.

The successful implementation of BI system plays an important role in understanding business status, measuring organization performance, improving relationship with stakeholders and creating profitable opportunities. A BI system Implementation is not a simple task requiring only the purchase of a combination of software and hardware; rather, it is a complex undertaking requiring appropriate infrastructure and resources over a lengthy period. Despite the vibrant BIS market and the complexities surrounding the implementation of BIS, the critical success factors (CSFs) of BIS implementation initiatives remain poorly understood [4, 5, 6, 2, 7, 8, 9, 10, 11].

A successful implementation of BIS enables experts and managers of companies to take better decisions. But according to [12, 11], risk of failure is high in implementing BI projects. Therefore, only 20% to 30% of BI projects are considered successful [11]. [13] Stated that billions of US dollars are spent on BI systems annually, but more than half of BI projects are ended with unrealized benefit. To implement a BI project successfully and to gain the associated benefits, we need not only to identify the factors leading to this success but also to prioritize these factors [14]. To rank and to prioritize the CSFs, several decision-making techniques are available such as Analytical Hierarchy Process (AHP), Analytical Network Process (ANP) and Interpretive Structural Modelling (ISM) etc. [14] stated that coalescing fuzzy set theory with AHP potentiates the accuracy of denouements.

This paper is organized as follow: Section 2 reviews the research context about BIS and CSF;

Section 3 is focused on the research methodology; Section 4 presents and analyzes the results; section 5 presents the paper conclusions.

2. LITERATURE SURVEY

The CSF of implementing BIS was addressed by several studies [6, 15, 16, 8, 4, 9, 10, 17]. [18] Proposed a model to assess the organizations' readiness to BIS. [19] Implemented Delphi technique to study CSF of BIS in public sector while [20] studied BIS in higher education sector. Some studies presented the success factors of specific BI projects in certain countries or certain sectors. The CSFs that affect BIS adoption within SAP-ERP On the other hand, there are several studies that implemented MCDM to address the CSF of ERPs. AHP was used to identify and rank the CSF in the implementation of ERP by [24]. The more sophisticated FAHP was also used by [25]. Moreover, TOPSIS (Technique for order preference by similarity to ideal solution) was also implemented for CSF of ERP by [26]. Therefore, like the CSF of ERP implementation, it is research worthy to apply a formal MCDM tool as FAHP to provide a general ranking of the CSF of BIS adaption. Consequently, the main aim of this work is to use such formal MCDM tool to validate or reject the existing literature

environment of Australia was explored by [21]. BIS adoption in Small and Medium Enterprises on the Upper Silesia, Poland were addressed by [2]. BIS adoption in financial sector of South Africa were addressed by [7], in hospital sector of Iran by [22] and in small and medium enterprises of Thailand, by [3]. Recently, [23] addressed CSF on BIS adoption in banking sector of Ghana.

To the best of our knowledge, none of the previous studies utilized one of the formal multicriteria decision making (MCDM) techniques to provide a generalized ranking of different CSFs of BIS despite the recommendation of [16].

conclusions about the CSF of BIS, which are mainly based on single case studies.

2.1 Critical Success Factors

Critical success factors (CSFs) are defined as the limited number of areas in which satisfactory results will ensure successful competitive performance for the individual, department or organization [4]. Many researchers addressed sixteen CSFs of BIS and classified them into four categories as shown in table-1.

Table 1. Critical Success Factors Of BIS

Categories	Organization					process			Technology						Environ ment	
Factors / Authors	Top management support	Clear vision	Adequate resource	Organizational culture	BI Strategic Alignment	Champion and Balanced team skills and composition	User oriented Change management	project management	Data quality	Integration between BI system and other systems	Scalable and flexible system	Compatibility	Complexity	Relative advantage	Selection of vendors	Competitive pressure
[6]	x	x	x			x	x	x	x		x					
[27]	x	x				x	x	x	x	x						
[9]	x	x				x	x	x	x		x					
[5]			x									x	x	x	x	x
[28]	x		x		x	x	x	x	x							
[29]	x			x			x		x							x
[21]	x											x	x	x	x	x
[18]	x					x	x		x							
[2]	x	x	x			x	x			x						
[30]						x	x									

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[8]	x	x		x			x	x	x		x			x	x	
[7]	x		x				x		x							
[31]									x	x	x					
[32]									x	x	x					
[15]	x	x	x		x	x	x									
[16]	x			x		x	x				x					
[4]	X		x		x	x	x	x	x							
[33]	x	x	x		x		x	x			x					
[34]	x	x				x			x		x					
[22]	x		x	x		x	x	x	x							
[35]	x	x	x	x		x	x	x	x		x				x	x
[36]												x	x	x		
[19]	x	x		x	x	x			x	x	x					
[37]	x		x										x			x
[11]	x	x	x		x	x	x	x	x		x					
[38]	x		x	x			x									
[17]												x	x	x		x
[39]	x	x				x	x	x	x		x					
[40]	x					x						x	x	x		x
[41]			x									x	x	x	x	x
[10]	x	x				x	x	x	x							
[20]	x			x	x											
[23]	x					x						x	x	x		x
[42]	x	x	x	x	x	x	x	x	x	x	x					
[43]	x			x					x							
[44]	x	x		x			x	x								
Total	29	15	14	11	8	20	22	14	20	6	13	7	8	8	5	9

Details of categories and factors are described as follow:

2.1.1 The organizational category:

The organizational category includes five factors. The top management support and the resource availability ensure the feasibility of the BIS projects. The organization culture, the business vision and BIS alignment increase the expected return of the project.

2.1.1.1 Top management support

Top management support encourages technology usage and gives better performance and is considered as one of the strongest enablers of technology implementation [21, 6, 45, 46, 17]. Top managers must have a leadership role that is driven by a sufficient commitment towards the organization. They provide the BI project with the required resource, skilled manpower and capital funds and all other resources, and minimizing the potential resistance caused by the internal structure of the organization.

2.1.1.2 Clear vision and well-established case

One of the most important factors in the BIS implementation project is the formulation of the vision. A strategic business vision is needed to direct the implementation of BIS, as a BIS initiative is driven by business [19, 10]. [9] Found that a long-term vision is needed to enable the establishment of BI business case. Business case should incorporate the expected benefits, estimated cost, the timeline, and what is required from the system. If the business vision is clear, understood, it would impact the adoption and outcome of the BIS. The business case that was derived from a detailed analysis of business needs would increase the chances of acquiring the support of top management and can encourage the adoption of a BIS to modify the current reporting and analytical processes [39, 10].

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2.1.1.3 Resources availability

Resources availability is an important factor for the implementation of BIS. Resources refer to financial resources, technological resources, people, and time [3]. Financial resources express an organization's capital available for IT investments. [47] stated that Managers will support the acceptance and adoption of new technology when capital, equipment, human resources and organizational time to implement technological innovation are available.

2.1.1.4 Organizational culture

Organizational culture is defined as the pattern of shared values and beliefs that helps individuals understand the organization functions and provides them with the norms of behavior in the organization .The coordination between the organizational culture and information system deems critical for organizations to gain the potential benefits from the system[19].To avoid employees resistance to adopting the new technology (BIS) There must be a good level of the support for continuous learning and improvement within the organization, organization must encourage the collaboration and cooperation across organizational units, and management must adopt the culture of "perform-and-reward" within the organization.

2.1.1.5 Align BIS with business strategy

To be successful and competitive organization, all BI plans should be aligned with business strategy [15]. By aligning BI and business strategies, not only business strategies bring about growth and development of BIS in organizations, but at the same time BIS strategies also lead to a change in and reorientation of business strategies.

2.1.2 The process category

The process category refers to: change management strategies that are centered on the users, Champion and balanced team composition, and Project management.

2.1.2.1 User oriented Change management

Change management is one of the most commonly accepted CSFs. Change management is a technique or strategy to properly manage the transformation from the use of older system to the use of new system suitably [10]. According to [28] Change Management involves the preparation of the various stakeholders for the expected changes and to assist them to cope and adapt to the transition. According to literature review this achieved through two aspects: user involvement through BIS implementation and user training.

User involvement: can contribute to better appreciation of their needs and format requirements, managing the user's expectations and satisfying user requirements. Sufficient user involvement reduces resistance from end users to use newer information technology.

Training: one of the most important factors to achieve success in BIS is users' awareness as it can reveal the benefits of the system and also necessity of its run for users in the organization. Users' awareness can be achieved through staff training. [8] Stated that appropriate training can help the users of organization to better understand the BIS function and solution, and to be more familiar with the operational procedure and make the BIS use more efficient and effective. Training can include various organizational levels such as operational and management levels.

2.1.2.2 Champion and balanced team composition

The BI team composition and skills have a major effect on the implementation success. Champion and balanced team composition factor include three components: the presence of champion, team skills, and external consultants [6, 9].

The champion: is defined as a person who has high enthusiastic and deep knowledge of the business and the technological innovation [9]. A Champion lead, support, and encourage the project actively. He plays an important role in gaining organizational acceptance and implementation of BI systems. He creates awareness, and provides information, political support, and material resources which impact successful adoption and implementation of innovation [48]. If organizations want to achieve higher adoption level of BIS, they need to appoint a project champion who has a good knowledge of both business process and BIS. Also the champion from business side is needed for such activities as data standardization, requirement engineering, data quality analysis, and testing [9, 10].

Team skills: BIS implementation team requires a people of different skills and experience. The project team generally should be cross-functional and from different business areas and consist of people with

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both strong business and technical knowledge. [28, 49].

External consultant: plays a critical role in BIS implementation, especially at early phase. External consultant is a person who has spent the majority of their time working on similar projects. The project team needs to include an external consultant to overcome the lack of in-house experience and competencies. External consultant could provide an unbiased view of solution to a problem with no fear of political outcomes [6, 9, 50].

2.1.2.3 Project Management

Project management supports the success of a BI system implementation. To concentrate on the best opportunity for improvement, the BI team should define the project scope and plan. Based on the Delphi of [6] ninety percent of the project success is determined prior to the first day. This success is based on having a very clear and well-communicated scope, having realistic expectations and timelines, and having the appropriate budget set aside.

2.1.3 The technological category:

The technological category includes: data quality, scalable and flexible system, integration between BIS system and other systems (e.g. ERP), relative advantage, compatibility, and complexity.

2.1.3.1 Data quality

The quality of data, specifically at the source systems, is a critical factor for the successful implementation of BI system [6, 9,32, 10, 4, 51]. The fundamental objective of the BI system is to integrate sources of data within organization for advanced analysis to improve the decision-making process. The data is extracted into the data warehouse and forms the basis for analysis and reporting. Most times, much data related problems within the back-end systems are not recognized until that data is populated and queried in the BI system [52, 6,9, 10]. To improve the quality of the data in back-end systems, the management is urged to initiate data governance and stewardship efforts. As unreliable data sources will have an effect on the BI applications and subsequently the decision outcomes [6,9]. So corporate data can only be fully integrated and facilitated for greater business value once its quality and integrity are assured [6,9, 19]. [45,53] mentions that more than 50 percent of BI projects have failed because of data quality issues. Also, they stated that customer data quality issues alone cost U.S. businesses over $600 billion dollars a year.

2.1.3.2 Scalable and flexible system:

BI flexibility is the amount of interaction that a BI system has with variety of data sources and analytical tools. Flexibility is a key capability to BI success [32]. BIS technical framework must be able to match scalability and extensibility requirements [6, 9]. Flexible and scalable infrastructure design allows for easy expansion of the system to align it with the evolving information needs.

2.1.3.3 Complexity of BI:

Boonsiritomachai et al. [3] defined complexity as the degree to which technology is difficult to understand and to use. [45] Mentioned that new ideas that are easier to learn are adopted more rapidly than those that require the adopters to develop new skills for understanding. BI needs to extract data from many sources prior to being transformed and loaded into a central repository so the complexity of establishing a BI environment is substantial [54]. The process of setting an environment for BI systems takes time and requires well-trained and dedicated staff [23]. Consequently, users with a weak IT and computing knowledge require a simple and stable solution that will meet their needs in the shortest time [3].

2.1.3.4 Relative advantage:

Relative advantage is defined as the degree to which an innovation is perceived as being better than existing ideas or systems [3]. Relative advantage is generally articulated in terms of social prestige, economic profitability, and other benefits such as cost reduction, savings in time, and improvement in decision making which normally depend on the nature of the innovation. Increasing the perceived benefits of an innovation accelerates its rate of adoption [45].

2.1.3.5 Compatibility:

Compatibility is defined as the degree to which an innovation is perceived as being consistent with existing values, past experiences and needs of potential adoption [3]. Consequently, an idea that is incompatible with the organization’s norms, values, and practices is not adopted as quickly as those that are compatible [23].If the applications appear to match the adopter’s processes the technological innovations will spread more easily and freely [45]. If the existing systems are not compatible with BI technologies, it will take a significant investment of time and resources to migrate and integrate data. The resultant high costs in money and time in these compatibility-related problems can clearly become a barrier to BIS adoption.

2.1.3.6 Integration between Business intelligence systems and other systems:

The integration of business intelligence with other systems can be defined as the degree of communicability of business intelligence with other systems. The integration can be at the data level, application level, business process level, or user level, yet these four levels are not isolated from each other [32]. So, these integrations can significantly benefit BI users through providing unified view of business data, a single personalized interface to the user, or a unified view of organization's business processes [32, 55]. As the main goal of a business intelligence system is uniting data stores for advance analysis to improve decision-making process [6]. So, the growing number and variety of data sources for BI in many organizations place increasing pressure on the integration between the systems from which the data are sourced.

2.1.4 The business environment category:

The business environment category comprises of the competitive pressure and the selection of vendors. Environmental factors are commonly and frequently used as a key determinant of innovation adoption.

2.1.4.1 Vendor selection:

Selecting a vendor is an environmental factor that affects the adoption of technology [56,3]. In general, it is the responsibility of vendors to provide the customers with software, hardware, user training, and technical support, to maintain their optimal performance.

2.1.4.2 Competitor's Pressure:

Competitive pressure is defined as the degree of stress that the company feels from competitors within the industry [57, 3, 23]. Competitive pressure encourages organizations to look for new approaches to raise their efficiency and increase productivity, which leads to achieving competitive advantage. Sometimes, pressure from an organizations external forces such as its partners, customers, and competition drives them to adopt an innovation. A competitor's pressure can lead to environmental uncertainty that could increase the rates of technology adoption in various industries [45].

3. METHODOLOGY

3.1 Fuzzy Analytical Hierarchy Process (FAHP)

There are many multicriteria decision making (MCDM) methods in use, The Analytic Hierarchy Process (AHP) is perhaps the most prominent and successful method of them. [58] introduced AHP as a decision aid to help solving unstructured problems in economics, social and management sciences and it has been applied in many practical applications in various fields from which CSFs ranking [59, 60, 61, 25; 62,63, 64, 24, 65,66].

AHP enables decision-makers to structure a complex problem in the form of a simple hierarchy and to evaluate a large number of quantitative and qualitative factors in a systematic manner under multiple criteria environment [67, 68, 69]. AHP helps decision makers to choose the best alternative by giving weight to each alternative based on certain criteria. The best alternative is the one with the highest weight.

Although the various benefits of AHP, it has some shortcomings. Most of the applications of AHP technique are materialized to closely crisp-information decisions; the AHP technique produces and conducts with a very unstable mode of decision making; this technique does not considers the mode of incertitude related the structuring the human judgment which may lead to biasness; the ranking done through this method is not precise, hence the judgment taken by the decision makers has a deep impact on the output obtained from AHP technique [70] .To break up these shortcomings and amending the incertitude related to AHP technique, various researchers amalgamated fuzzy set theory with AHP. The fuzzy AHP method is considered to be one of the globally adopted techniques used for prioritizing and raking purposes [14]. Fuzzy logic is a proven scientific technique that allows us to convert linguistic measures into crisp measure using membership Functions [71]. Inclusion of fuzzy with AHP has enhanced the accuracy of the solutions.

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A review of the literature reveals the intensity of use fuzzy AHP by researchers for solving their problem. [72] applied an integrating fuzzy AHP and fuzzy TOPSIS methods to evaluate performance. While [73] used Fuzzy TOPSIS to rank the solutions of knowledge management adoption in supply chain to overcome its barriers. [74] used fuzzy AHP in human resource management. Also [14] applied Fuzzy AHP to Prioritize the Barriers of Integrated Lean Six Sigma.

The Fuzzy Set Theory

Fuzzy sets are sets whose elements have degrees of membership. The fuzzy set theory has been introduced by Zadeh [75] and is designed to deal with the extraction of the possible outcome from a variety of information expressed in vague and imprecise terms [60, 76]. In fuzzy logic elements are mapped to degree of membership function under defined interval mostly [0, 1]. Accordingly, if 0 value is allotted, it means the element does not belong to defined set; whereas if 1 is allotted, it means that the element completely belongs to the set. But if the allotted value lies between the range of 0 and 1, then it describes the degree of membership of that element. To undertake the equivocalness considered in linguistic estimation, it is amended to convert them into fuzzy numbers [14].

In our study each linguistic variable is defined by triangular fuzzy number (TFN) because of its simplicity and computational efficiency and it is most frequently used [77, 78, 72]. A triangular fuzzy number should possess the basic features as following: The fuzzy number A on a real number (R) to be a triangular fuzzy number if its membership function m A (x): R [0,1] is defined as [79]:

$$\mu A\ (x) = \begin{cases} \frac{x-l}{m-l}, & l \le x \le m \\ \frac{u-x}{u-m}, & m \le x \le u \\ 0 & otherwise \end{cases}$$

TFN can be denoted by $A = (l, m, u)$, Where l and u represent the lower and upper bounds of the fuzzy number A , respectively, and *m* is the most promising value of the fuzzy number *A* as shown in figure- 1.

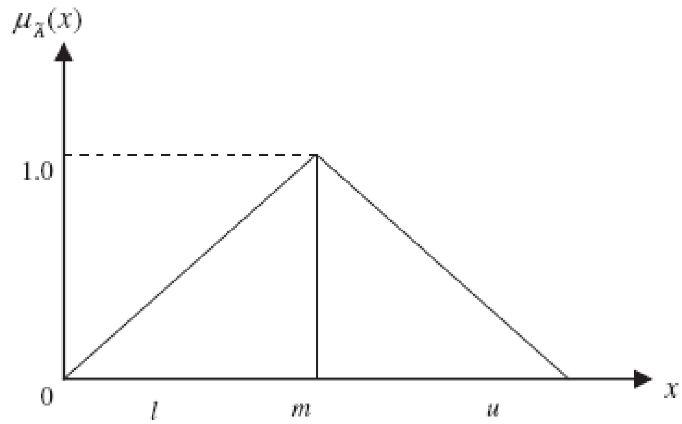

Figure -1. The membership functions of the triangular fuzzy number (adapted from [72]).

The operational laws of two triangular fuzzy numbers $A1 = (l1, m1, u1)$ and $A2 = (l2, m2, u2)$:

Fuzzy number addition:

$$A1 \oplus A2 = (l1, m1, u1) \oplus (l2, m2, u2) = (l1 + l2, m1 + m2, u1 + u2)$$

Fuzzy number subtraction:

$$A1 \Theta A2 = (l1, m1, u1) \Theta (l2, m2, u2) = (l1 - u2, m1 - m2, u1 - l2)$$

Fuzzy number multiplication:

$$A1 \otimes A2 = (l1, m1, u1) \otimes (l2, m2, u2) = (l1 * l2, m1 * m2, u1 * u2) \text{ for } l1, m1, u1, l2, m2, u2 > 0$$

Fuzzy number division:

$$A1 \oslash A2 = (l1, m1, u1) \oslash (l2, m2, u2) = \left(\frac{l1}{u2}, \frac{m1}{m2}, \frac{u1}{l2}\right) \text{ for } l1, m1, u1, l2, m2, u2 > 0$$

Fuzzy number reciprocal:

$$(A)^{-1} = (l, m, u)^{-1} = \left(\frac{1}{u}, \frac{1}{m}, \frac{1}{l}\right) \text{ for } l, m, u > 0$$

3.2 The Steps to Execute Fuzzy AHP

The fuzzy AHP technique is one of the globally used methods for prioritizing and raking because integrating fuzzy with AHP has improved the accuracy of the solutions. According to [80] the following steps are used to Execute Fuzzy AHP:

1. The decision group (Experts)

A list of experts with information technology implementation experience of at least ten years is created. Then,

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fifty of them were short listed based on their BI projects implementation experience. The FAHP questionnaire was emailed to the short-listed experts and they were asked for a meeting (face to face or online). Fourteen of them (28%) responded positively. The fourteen positive responses obtained from experts work in: Egypt, United Arabic Emirates, Saudi Arabia, China, Hong Kong, and Brazil.

2. Constructing the hierarchy

To rank the CSF of BI systems, a three level AHP model is created. The first level represents the goal of the model, which is to prioritize BIS CSFs, while the second level represents the four categories of BIS CSFs. The factors within each category are used as alternatives or sub criteria of the model at the third level. The complete AHP model is shown in Figure- 2.

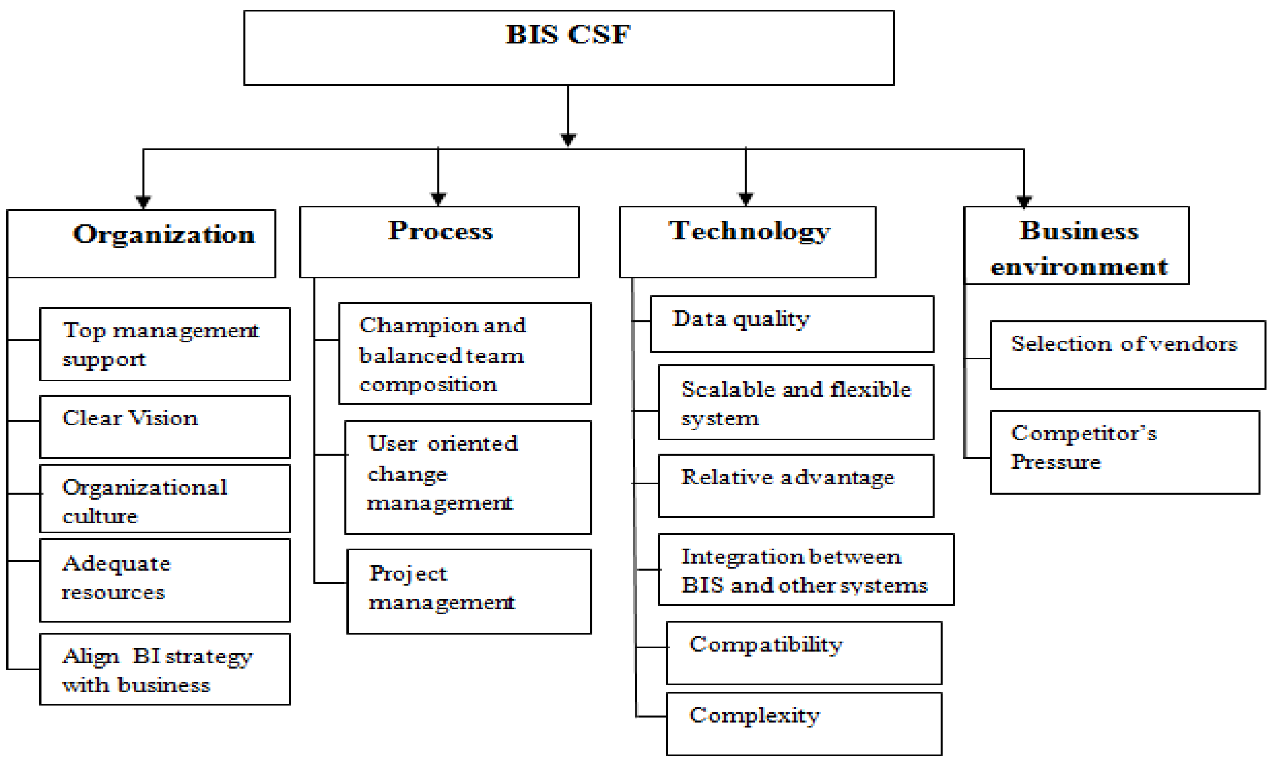

Figure- 2. Hierarchical structure for prioritization of critical success factors of BIS

3. The linguistic variables:

A linguistic variable is a variable whose values are words or sentences in a natural or artificial language. Nine linguistic terms are used to express the comparison of the importance of the different CSFs of BIS implementation, as shown in table-2.

Table-2. Membership function of linguistic scale (scale of fuzzy number) [81]

Fuzzy number	Scale of fuzzy number	Linguistic
1	(1, 1,1)	Equal
2	(1, 2,3)	Weak advantage
3	(2, 3,4)	Not bad
4	(3, 4,5)	Preferable
5	(4, 5,6)	Good
6	(5, 6,7)	Fairly good
7	(6, 7,8)	Very good
8	(7, 8,9)	Absolute
9	(8, 9,10)	Perfect

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4. The fuzzy pairwise comparison matrix

The pairwise comparison matrix is the key to transform subjective priorities to computable values according to decision makers' preferences. The ratio scale is used to capture the relative importance (weights) of all decision elements. Pairwise comparisons of these elements within the same hierarchical level with respect to the parent elements in the next higher level are established. The pairwise comparisons are usually filled by experts through questionnaire. The comparison takes the form: How important is element 1 when compared to element 2 with respect to the element above?

The FAHP uses a consistency rate (CR) to measure the consistency of judgment of the decision makers. A Consistency Index (CI) is used to measure the degree of inconsistency in the respond matrix. The consistency ratio (CR) is the ratio of CI to random consistency index (RCI) of the matrix size. Generally, a CR of 0.10 or less is considered acceptable; otherwise the respond matrix A is considered to contain high randomness and inconsistent. Tables-3 show values of RCI for matrices of size of 1 to 8 [72].

Table-3. Random consistency index

Size of the Matrix(n)	1	2	3	4	5	6	7	8
Random Index(RI)	0	0	0.58	0.90	1.12	1.24	1.32	1.41

Computing the CR of the fourteen obtained response matrices resulted in accepting twelve questionnaires and excluding two questionnaires because their calculated CRs are higher than the 0.1 threshold.

5. Calculating the criteria weight

The below numerical example illustrates, how the weight of the factors of process category criteria are calculated. The weights of other factors are calculated in a similar way. The process category includes three factors: champion and balanced team composition, user-oriented change management, and project management. After fuzzifying the responses of the twelve consistent questionnaires, the geometric mean of the twelve fuzzy responses is calculated to obtain an aggregated response:

$$D_{ij} = (D^1_{ij} \otimes D^2_{ij} \otimes D^3_{ij} \otimes D^4_{ij} \ldots\ldots \otimes D^f_{ij})^{1/f}$$

Where D^f_{ij} represent a subjective judgment of the f^{th} expert for the relative importance of i^{th} criterion to the j^{th} criterion. For example, the aggregated fuzzy importance of champion to user-oriented change management ($D_{\text{champion, user}}$) is calculated as:

$$d12\,(\text{Champion, User}) = \left((6,7,8) \otimes (4.5.6) \otimes (1,1,1) \ldots\ldots \otimes (2,3,4)\right)^{1/12}$$

$$d12\,(\text{Champion, User}) = (.78, .89, 1)$$

Similarly, the synthetic pairwise comparison matrix of the process category is constructed as:

$$A = \begin{array}{c} \\ \text{Champion} \\ \text{User} \\ \text{Project} \end{array} \begin{array}{ccc} \text{Champion} & \text{User} & \text{Project} \\ (1, 1, 1) & (0.78, 0.89, 1) & (0.47, 0.55, 0.63) \\ (1, 1.13, 1.28) & (1, 1, 1) & (0.79, 0.96, 1.15) \\ (1.58, 1.82, 2.12) & (0.87, 1.04, 1.27) & (1, 1, 1) \end{array}$$

The un normalized fuzzy weight of each factor (Si) is calculated as:

$$S_{\text{champion}} = (a_{11} \otimes a_{12} \otimes a_{13})^{\frac{1}{3}}$$

$$= (1 * 0.78 * 0.47)^{\frac{1}{3}}, (1 * 0.89 * 055)^{\frac{1}{3}}, (1 * 1 * 0.63)^{\frac{1}{3}}$$

$$= (0.72, 0.79, 0.86) \otimes (1/3.39, 1/3.05, 1/2.75)$$

$$= (0.72, 0.79, 0.86) \otimes (0.295, 0.327, 0.364)$$

$$= (0.211, 0.258, 0.312)$$

Similarly, the fuzzy weights of the user and project factors are calculated:

$$\grave{w}_{user} = (0.272, 0.336, 0.4142)$$

$$\grave{w}_{project} = (0.328, 0.406, 0.506)$$

6. Defuzzification of the weight

The defuzzification method introduced by [72] is used to convert the fuzzy weights into crisp ones:

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$$W = [(U(\grave{w}) - L(\grave{w})) + (M(\grave{w}) - L(\grave{w}))]/3 + L(\grave{w})$$

$$W_{champion} = \frac{[(0.312 - 0.211) + (0.258 - 0.211)]}{3} + 0.211 = 0.260$$

Similarly, the crisp weights of the other two factors are calculated, as shown in table -4.

7. Prioritizing each criterion

Finally, each creation is ranked based on its weight as shown
in table-4 for the process category. Using the same illustrated last three steps, the ranks of the factors of each category are calculated.

Table-4. Weights Of Factors

Factor	Fuzzy Weights ($\grave{w}$)	Crisp weight (w)	Rank
Champion and balanced team composition	(0.211,0.258,0.312)	0.260	3
User oriented change management	(0.272,0.336,0.414)	0.341	2
Project management	(0.328,0.406,0.506)	0.413	1

$$= (0.72, 0.79, 0.86)$$

$$S_{user} = (0.92, 1.03, 1.14)$$

$$S_{project} = (1.11, 1.24, 1.39)$$

The normalized fuzzy weight of champion factor is done as:

$$\grave{w}_{champion} = S_{champion} \otimes (S_{champion} \oplus S_{user} \oplus S_{project})^{-1}$$

$$= (0.72, 0.79, 0.86) \otimes ((2.75, 3.05, 3.39)^{-1}$$

4. RESULTS

As shown in table-5 the organizational category and the technological one has almost the same importance weights as 0.343 and 0.342 respectively. On the other hand, the process category and the environmental category have lower importance weights of 0.179 and 0.166. Vendor selection has the highest local weight of 0.660 followed by the project management, competition pressure, User oriented change management, and the top management support.

Table-6 shows the global weights of CSFs ranking calculated by multiplying the local weights of each CSF by the global weight of each category. By doing this, each local CSF is

Table-5. Global and local Weights

Category	Global weight	CSFs	Local weights
Technology	0.342 (2)	• Data quality • Scalable and flexible system • Relative advantage • Compatibility • Integration between BIS and other systems • Complexity	0.213(1) 0.213(1) 0.205(2) 0.182(3) 0.172(4) 0.034(5)
Organization	0.343 (1)	• Top management support • adequate resource • Align BI strategy with business objectives. • Organizational culture • Clear Vision	0.336(1) 0.254(2) 0.203(3) 0.122(4) 0.113(5)
Process	0.179 (3)	• Project management • User oriented change management • Champion and balanced team composition	0.413(1) 0.341(2) 0.260(3)
Environment	0.166 (4)	• Selection of vendors • Competitive pressure	0.660(1) 0.345(2)

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Table-6. CSF Ranking With Global Weights

CSFs	Global weights	Category
Top management	0.115	Organization
Selection of vendors	0.110	Environment
adequate resource	0.087	Organization
Project management	0.074	Process
Data quality	0.073	Technology
Scalable and flexible system	0.073	Technology
Relative advantage	0.070	Technology
Align BI strategy with business objectives.	0.070	Organization
Compatibility	0.062	Technology
User oriented change management	0.061	Process
Integration between BIS and other systems	0.059	Technology
Competitive pressure	0.057	Environment
Champion and balanced team composition	0.047	Process
Organizational culture	0.042	Organization
Clear Vision	0.039	Organization
Complexity	0.012	Technology

Data quality (0.073) is important to improve the decision-making process. Scalable and flexible system design (0.073) allows for easy expansion of the system to align it with evolving information needs. Relative advantage (0.070) motivates organizations to allocate the needed resources and tolerate the hassles of implementing the new technology. Align BI strategy with business objectives (0.070) acquires the support of top managers. The remaining eight factors have importance weight less than the average (0.0625) and can be considered less significant to the success of the BIS projects.

balanced by the importance of the category to which it belongs.

Top management (0.115) has the highest priority followed by the Selection of vendors (0.110). Vendors' support includes technical

assistance, training, compensating for the lack of internal IT experts.

Adequate resource (0.087) has the third priority. Based on its high local weight as the most important factor of the process category, project management (0.074) ranked the forth critical success factor. BIS project success is based on having a clear

Comparing the above ranking of CSF of BIS to the ranking provided by previous stiudies reveals some interesting insights. As shown in figure-3, top management support is highly ranked by the surveyed experts as the top critical success factor of BI. The high importance of the top management support is suggested by other studies for both ERP and BI systems. Studies rank it as the top or one of the top three CSF of both BI and ERP systems. Moreover, the importance of adequate resourcing, project management, data quality and system scalability as BI success factors is emphasized by both of the surveyed experts and the literature.

Moving clockwise, it can be concluded that strategic alignment and change management were highly ranked by the existing literature. However, the surveyed experts underestimated the importance of those factors compared to the earlier ones. This conflict can be explained that the current studies are based on single cases without the usage of structured MCDM tools. Despite that none of the surveyed studies assigned a high rank for vendor selection as CSF of BI systems, the surveyed experts ranked it the second most important CSF. The literature shows a relative importance of vendor selection as a CSF of ERP implementation [83, 84, 85].

Moreover, relative advantage, compatibility, current system integrations, and competition pressures are moderately ranked by surveyed experts while been ignored by the literature. Project complexity is considered insignificant by the surveyed experts is ignored by the BI literature. The organization culture, champion and visions are also considered insignificant by the experts, while being highly ranked by existing literature.

and well-communicated scope along with realistic expectations and timelines.

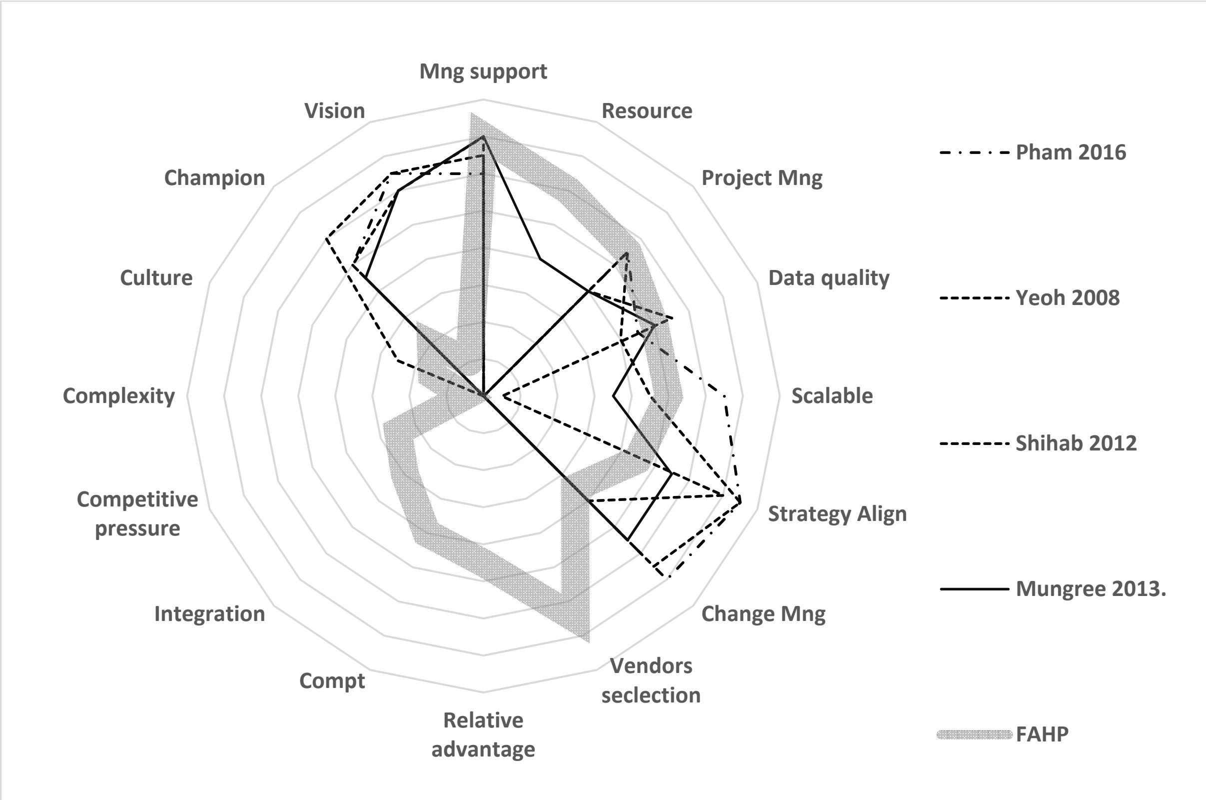

Figure-3. Comparing The Rank Of CSF As Obtained From The Surveyed Experts Using FAHP To -The Rank Provided By Previous BIS Studies [6, 15, 82, 11]

5. CONCLUSION AND FUTURE WORK

To implement BIS successfully, it is very important to identify and prioritize the CSFs so that the organization can focus on the CSFs that have the high priority. A multi criteria decision making technique (FAHP) was applied to prioritize the CSFs related to BIS implementation. Based on the feedback of 12 BIS experts, some insights about the importance of CSFs of BIS match the findings of the previous studies:

- Some prior studies suggested that technology category has a higher priority than organizational category and others found that organizational category has a higher priority than technology category. The surveyed experts ranked both categories at the same importance.
- The most important CSF is the top management support, which confirms the findings of the earlier studies of BIS.
- Both the surveyed experts and the previous literature agreed on the importance of adequate resourcing, project management, data quality and system scalability.

On the other hand, some findings of the study do not match the reported recommendations of the earlier studies:

- Despite being ignored by earlier BIS studies, vendor selection was ranked the second most important success factor of BIS.
- Perceived relative advantage is an important CSF for BI despite being ignored by the previous literature
- Align BI strategy with business objectives, champion and balanced team composition, organizational culture, and clear vision are not as important as reported by earlier BIS studies.

It is research worthy to use different ranking techniques such as Analytical Network Process (ANP), Interpretive Structural Modelling (ISM), and

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TOPSIS to rank the CSFs of BIS. Moreover, determining the impact of each factor on the post implementation performance indicators is an interesting topic to size the time and the money to be invested in each of those factors.

The surveyed experts are from five different countries. Therefore, the resulting ranking is aggregated across those countries. The technological and the market landscape of a specific country may result in different ranking than the presented one. Moreover, it should be noticed that none of the surveyed experts has implemented BI projects in the fields of oil and gas or agriculture. Therefore, the validity of the results for such fields need further investigation.

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